

What is claimed is:

1 1. In a steering control device equipped with: a turning mechanism including a
2 turning actuator driving a position-controllable turning shaft; and a steering angle sensor
3 detecting a steering angle θ of a steering wheel,
4 a steering control device comprises:
5 a turning displacement sensor detecting a turning displacement X ($-X_E \leq X \leq$
6 $+X_E$) in said turning mechanism; and
7 means for calculating a turning instruction value calculating an instruction value
8 for a turning displacement in said turning mechanism based on said steering angle θ ;
9 wherein:
10 said turning instruction value calculating means includes means for generating
11 hysteresis characteristics calculating, in exceptional situations where an absolute value
12 $|\theta|$ of said steering angle θ exceeds a predetermined threshold value θ_E corresponding to
13 an upper limit X_E of said turning displacement X , said instruction value X_n based on: a
14 vertical axis coordinate corresponding to said steering angle θ on a predetermined
15 hysteresis loop with one side being a section of a line $X_n = \pm X_E$ on a θ - X_n plane; and a
16 steering direction (steering direction/restoring direction) of said steering wheel.

1 2. A steering control device as described in claim 1 wherein a steering
2 mechanism including said steering wheel and said turning mechanism are mechanically
3 separated, and an electrical coupling mechanism substitutes for a connecting mechanism
4 connecting said steering mechanism and said turning mechanism.

1 3. A steering control device as described in claim 1 further comprising means
2 for setting an endpoint setting a target coordinate for an endpoint P_O that closes said
3 hysteresis loop.

1 4. A steering control device as described in claim 2 further comprising means for
2 setting an endpoint setting a target coordinate for an endpoint P_O that closes said hysteresis
3 loop.

1 5. A steering control device as described in claim 3 wherein said endpoint setting
2 means includes means for varying a target point dynamically varying said target coordinate
3 for said endpoint P_O based on a steering velocity ω ($= d\theta/dt$), a steering torque τ , said
4 steering angle θ , said steering direction, or an automobile velocity v .

1 6. A steering control device as described in claim 4 wherein said endpoint setting
2 means includes means for varying a target point dynamically varying said target coordinate
3 for said endpoint P_O based on a steering velocity ω ($= d\theta/dt$), a steering torque τ , said
4 steering angle θ , said steering direction, or an automobile velocity v .

1 7. A steering control device as described in claim 1 wherein, using a function $f(\theta)$
2 of said steering angle θ , symmetrical around the origin, and a correction gain G ($0 < G \leq 1$),
3 said hysteresis loop on said θ - X_n plane is formed as a closed curve from said line $X_n = +/-$
4 X_E , a curve $X_n = f(\theta)$, and a curve $X_n = Gf(\theta)$.

1 8. A steering control device as described in claim 2 wherein, using a function $f(\theta)$
2 of said steering angle θ , symmetrical around the origin, and a correction gain G ($0 < G \leq 1$),
3 said hysteresis loop on said θ - X_n plane is formed as a closed curve from said line $X_n = +/-$
4 X_E , a curve $X_n = f(\theta)$, and a curve $X_n = Gf(\theta)$.

1 9. A steering control device as described in claim 3 wherein, using a function $f(\theta)$
2 of said steering angle θ , symmetrical around the origin, and a correction gain G ($0 < G \leq 1$),
3 said hysteresis loop on said θ - X_n plane is formed as a closed curve from said line $X_n = +/-$
4 X_E , a curve $X_n = f(\theta)$, and a curve $X_n = Gf(\theta)$.

1 10. A steering control device as described in claim 4 wherein, using a function $f(\theta)$
2 of said steering angle θ , symmetrical around the origin, and a correction gain G ($0 < G \leq 1$),
3 said hysteresis loop on said θ - X_n plane is formed as a closed curve from said line $X_n = \pm$
4 X_E , a curve $X_n = f(\theta)$, and a curve $X_n = Gf(\theta)$.

1 11. A steering control device as described in claim 5 wherein, using a function $f(\theta)$
2 of said steering angle θ , symmetrical around the origin, and a correction gain G ($0 < G \leq 1$),
3 said hysteresis loop on said θ - X_n plane is formed as a closed curve from said line $X_n = \pm$
4 X_E , a curve $X_n = f(\theta)$, and a curve $X_n = Gf(\theta)$.

1 12. A steering control device as described in claim 6 wherein, using a function $f(\theta)$
2 of said steering angle θ , symmetrical around the origin, and a correction gain G ($0 < G \leq 1$),
3 said hysteresis loop on said θ - X_n plane is formed as a closed curve from said line $X_n = \pm$
4 X_E , a curve $X_n = f(\theta)$, and a curve $X_n = Gf(\theta)$.

1 13. A steering control device as described in claim 7 further comprising means for
2 calculating correction gain calculating a value for said correction gain G based on said
3 upper limit X_E and said function $f(\theta)$.

1 14. A steering control device as described in claim 8 further comprising means for
2 calculating correction gain calculating a value for said correction gain G based on said
3 upper limit X_E and said function $f(\theta)$.

1 15. A steering control device as described in claim 9 further comprising means for
2 calculating correction gain calculating a value for said correction gain G based on said
3 upper limit X_E and said function $f(\theta)$.

1 16. A steering control device as described in claim 10 further comprising means for
2 calculating correction gain calculating a value for said correction gain G based on said

3 upper limit X_E and said function $f(\theta)$.

1 17. A steering control device as described in claim 11 further comprising means for
2 calculating correction gain calculating a value for said correction gain G based on said
3 upper limit X_E and said function $f(\theta)$.

1 18. A steering control device as described in claim 12 further comprising means for
2 calculating correction gain calculating a value for said correction gain G based on said
3 upper limit X_E and said function $f(\theta)$.

1 19. A steering control device as described in claim 7 further comprising means for
2 asymptote normalization monotonically increasing said correction gain G ($0 < G \leq 1$) in a
3 dynamic manner based on a steering amount S , a steering status, a turning amount Z , or a
4 turning status after initiation of restorative steering having as a starting point said line $X_n =$
5 $\pm X_E$.

1 20. A steering control device as described in claim 13 further comprising means for
2 asymptote normalization monotonically increasing said correction gain G ($0 < G \leq 1$) in a
3 dynamic manner based on a steering amount S , a steering status, a turning amount Z , or a
4 turning status after initiation of restorative steering having as a starting point said line $X_n =$
5 $\pm X_E$.

1 21. A steering control device as described in claim 19 wherein said asymptote
2 normalizing means includes means for varying an asymptote rate using a steering velocity
3 $\omega (= d\theta/dt)$, a steering torque τ , said steering angle θ , said steering direction, or an
4 automobile velocity v , in order to dynamically change an asymptote rate $A (= dG/dS)$ for
5 said steering amount S of said correction gain G or an asymptote rate $B (= dG/dZ)$ for said
6 turning amount Z of said correction gain G when said correction gain G ($0 < G \leq 1$) is
7 being monotonically increased in a dynamic manner.

1 22. A steering control device as described in claim 20 wherein said asymptote
2 normalizing means includes means for varying an asymptote rate using a steering velocity
3 $\omega (= d\theta/dt)$, a steering torque τ , said steering angle θ , said steering direction, or an
4 automobile velocity v , in order to dynamically change an asymptote rate $A (\equiv dG/dS)$ for
5 said steering amount S of said correction gain G or an asymptote rate $B (\equiv dG/dZ)$ for said
6 turning amount Z of said correction gain G when said correction gain G ($0 < G \leq 1$) is
7 being monotonically increased in a dynamic manner.

1 23. A steering control device as described in claim 1 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 24. A steering control device as described in claim 2 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 25. A steering control device as described in claim 3 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 26. A steering control device as described in claim 5 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 27. A steering control device as described in claim 7 further comprising means for

2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 28. A steering control device as described in claim 13 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 29. A steering control device as described in claim 19 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 30. A steering control device as described in claim 22 further comprising means for
2 varying a steering angle threshold dynamically changing upper and lower limits of a
3 predetermined tolerance range ($-\theta_E \leq \theta \leq \theta_E$) of said steering angle θ based on an
4 automobile velocity v .

1 31. A steering control device as described claim 1 wherein said steering mechanism
2 includes means for generating endpoint reactions generating, at a vicinity of an upper limit
3 position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$ of said
4 steering angle θ , a virtual abutment resistance restricting said steering angle θ from
5 exceeding a predetermined tolerance range ($-\theta_R \leq \theta \leq \theta_E$), based on said steering angle θ ,
6 said turning displacement X , or an instruction value X_n for said turning displacement X .

1 32. A steering control device as described claim 2 wherein said steering mechanism
2 includes means for generating endpoint reactions generating, at a vicinity of an upper limit
3 position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$ of said

steering angle θ , a virtual abutment resistance restricting said steering angle θ from exceeding a predetermined tolerance range ($-\theta_R \nlessgtr \leq \theta_E$), based on said steering angle θ , said turning displacement X , or an instruction value X_n for said turning displacement X .

33. A steering control device as described claim 3 wherein said steering mechanism includes means for generating endpoint reactions generating, at a vicinity of an upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$ of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from exceeding a predetermined tolerance range ($-\theta_R \nlessgtr \leq \theta_E$), based on said steering angle θ , said turning displacement X, or an instruction value X_n for said turning displacement X.

34. A steering control device as described claim 5 wherein said steering mechanism includes means for generating endpoint reactions generating, at a vicinity of an upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$ of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from exceeding a predetermined tolerance range ($-\theta_R \nlessgtr \leq \theta_E$), based on said steering angle θ , said turning displacement X, or an instruction value X_n for said turning displacement X.

35. A steering control device as described claim 7 wherein said steering mechanism includes means for generating endpoint reactions generating, at a vicinity of an upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$ of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from exceeding a predetermined tolerance range ($-\theta_R \nlessgtr \leq \theta_E$), based on said steering angle θ , said turning displacement X, or an instruction value X_n for said turning displacement X.

36. A steering control device as described claim 13 wherein said steering mechanism includes means for generating endpoint reactions generating, at a vicinity of an upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$ of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from

5 exceeding a predetermined tolerance range ($-\theta_R \nless \leq \theta_E$), based on said steering angle θ ,
6 said turning displacement X, or an instruction value X_n for said turning displacement X.

1 37. A steering control device as described claim 19 wherein said steering
2 mechanism includes means for generating endpoint reactions generating, at a vicinity of an
3 upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$
4 of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from
5 exceeding a predetermined tolerance range ($-\theta_R \nless \leq \theta_E$), based on said steering angle θ ,
6 said turning displacement X, or an instruction value X_n for said turning displacement X.

1 38. A steering control device as described claim 22 wherein said steering
2 mechanism includes means for generating endpoint reactions generating, at a vicinity of an
3 upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$
4 of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from
5 exceeding a predetermined tolerance range ($-\theta_R \nless \leq \theta_E$), based on said steering angle θ ,
6 said turning displacement X, or an instruction value X_n for said turning displacement X.

1 39. A steering control device as described claim 23 wherein said steering
2 mechanism includes means for generating endpoint reactions generating, at a vicinity of an
3 upper limit position θ_E of said steering angle θ and at a vicinity of a lower limit position $-\theta_E$
4 of said steering angle θ , a virtual abutment resistance restricting said steering angle θ from
5 exceeding a predetermined tolerance range ($-\theta_R \nless \leq \theta_E$), based on said steering angle θ ,
6 said turning displacement X, or an instruction value X_n for said turning displacement X.